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(54) Fluid actuator

(57) A fluid actuator for a vehicle suspension system includes two flexible-wall fluid-filled bags 2, 3 and a piston assembly 5 coupled to a suspension joint 17 and including cone-shaped portions 16, 16a engaging the bags. If a vehicle wheel hits a bump, the assembly rises displacing fluid from bag 2, at an increasing rate due to the shape of the portion 16. The restoring force on the piston is thus correspondingly increased. The bags may be independently supported by a pair of pistons (figure 7). The bags may be substantially rigid with fl xible diaphragms engaging the piston (figures 8, 9).

Fig 1.

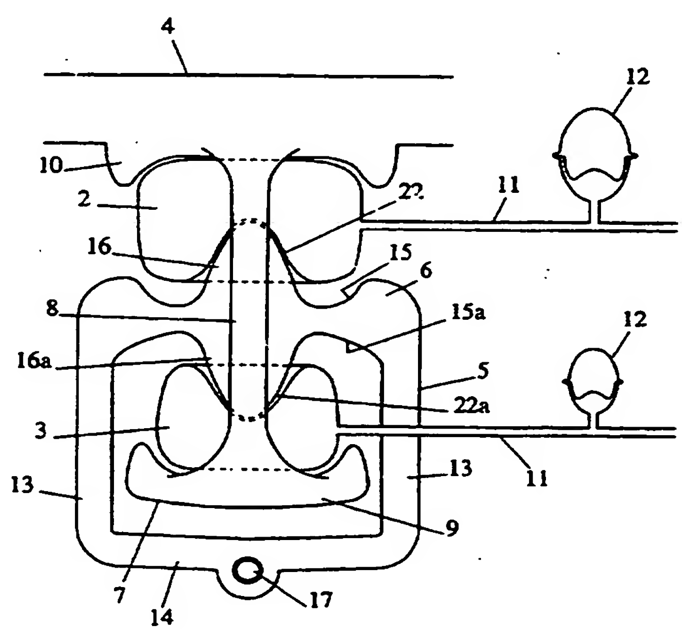

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Fig 1.

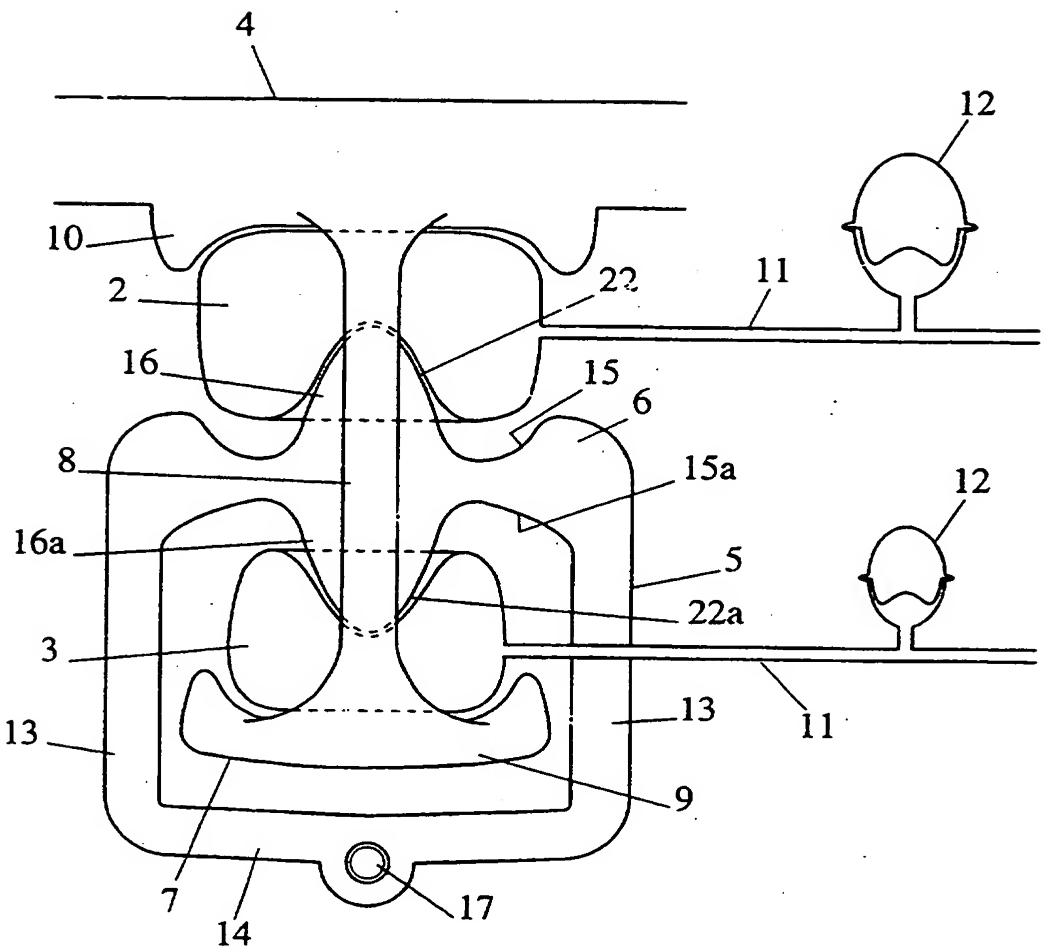


Fig 2.

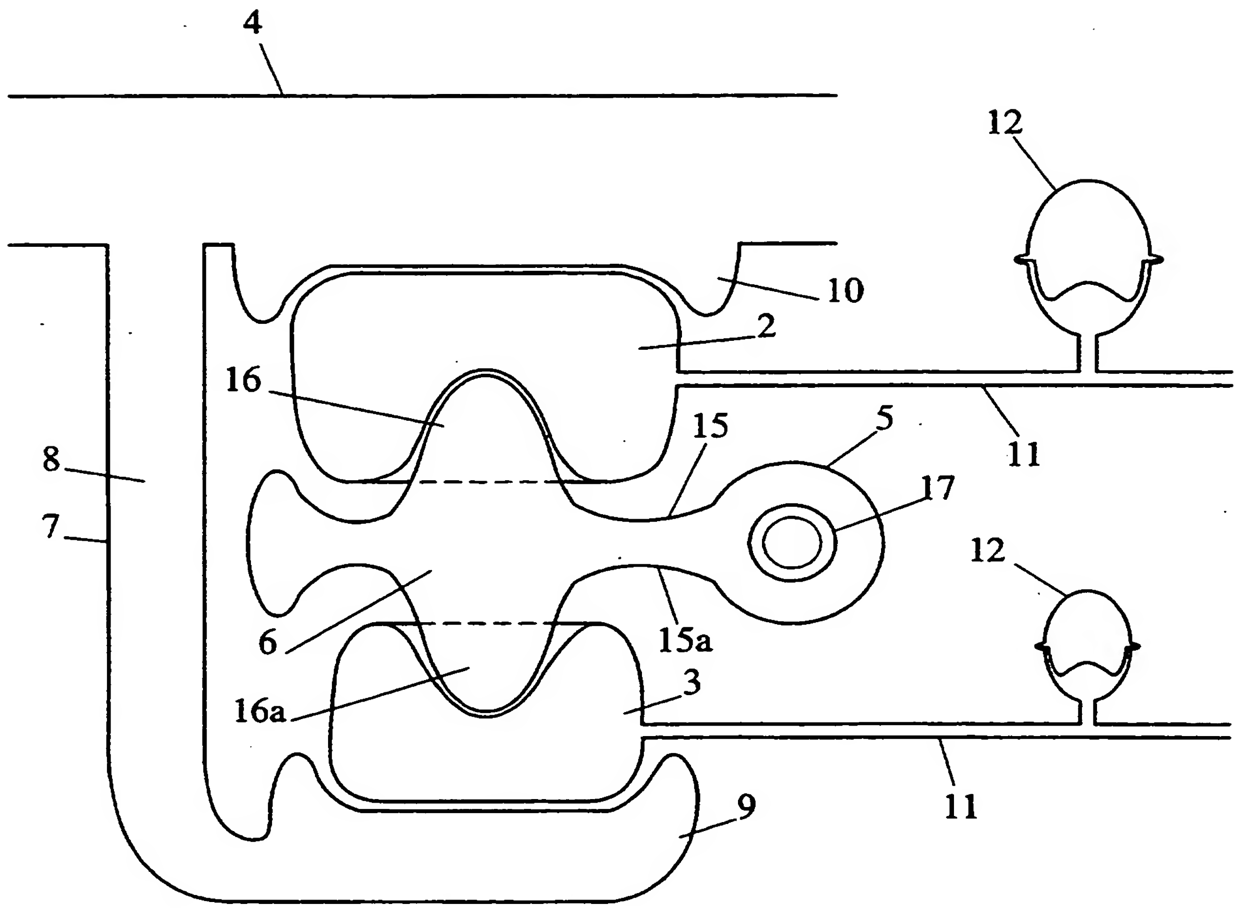


Fig 3.

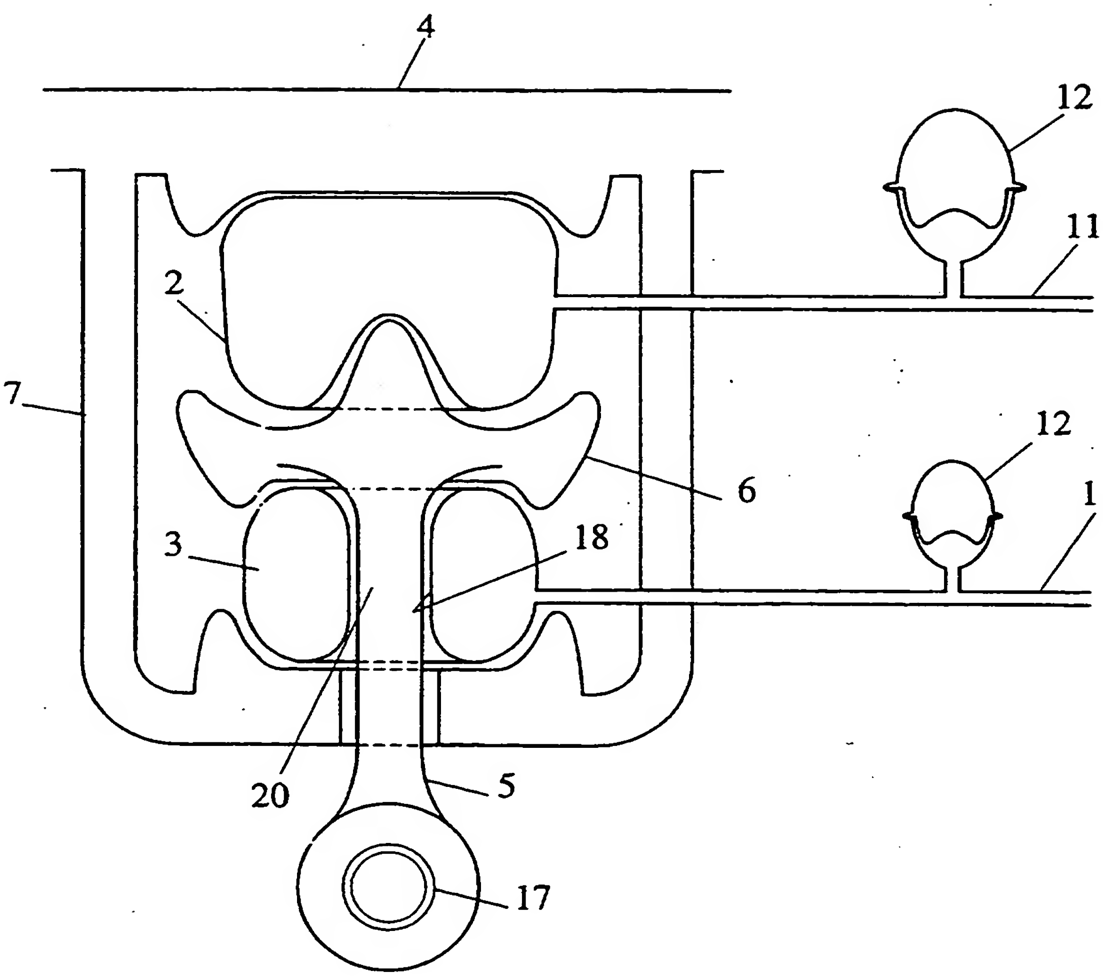


Fig. 4

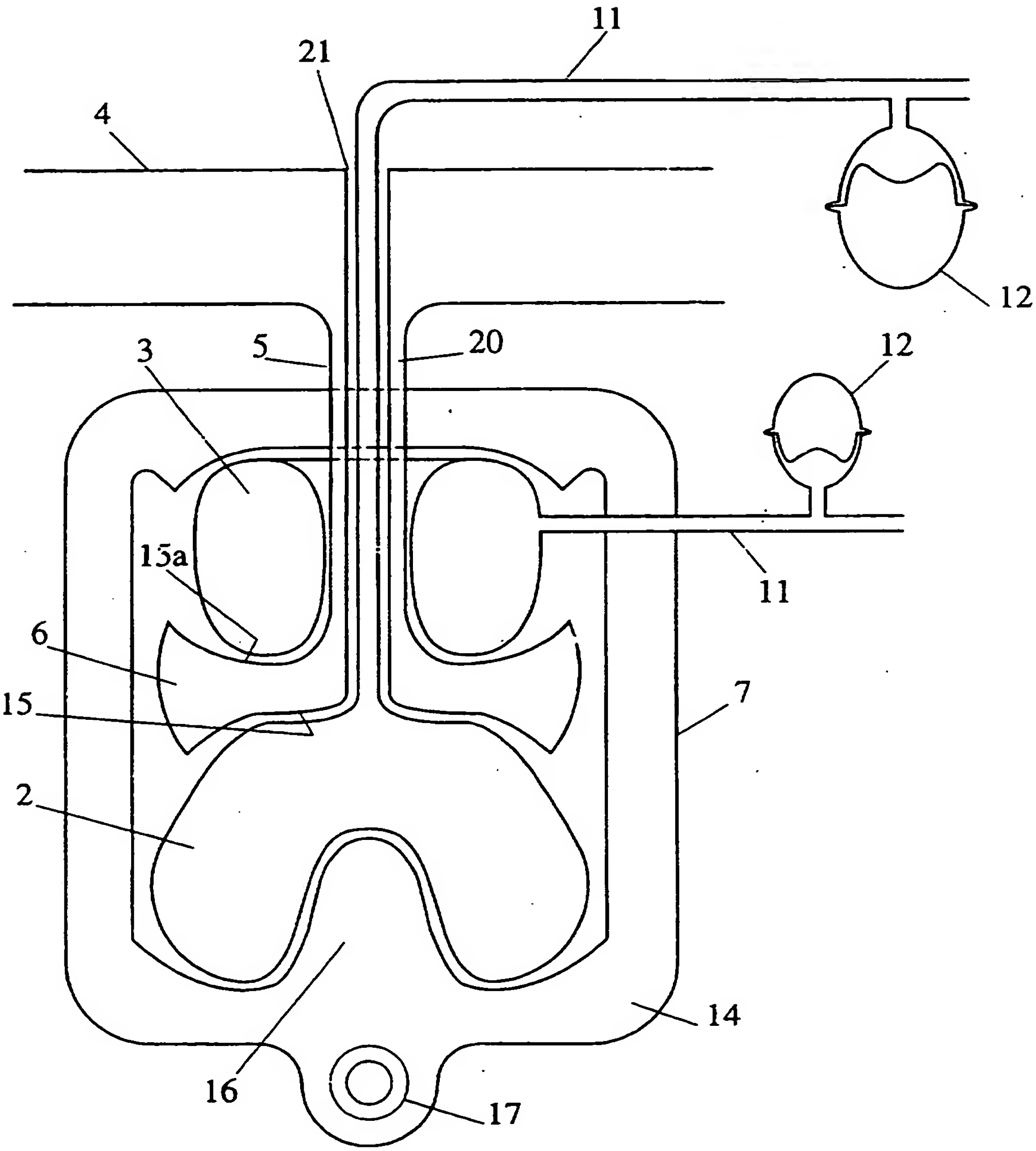


Fig 5.

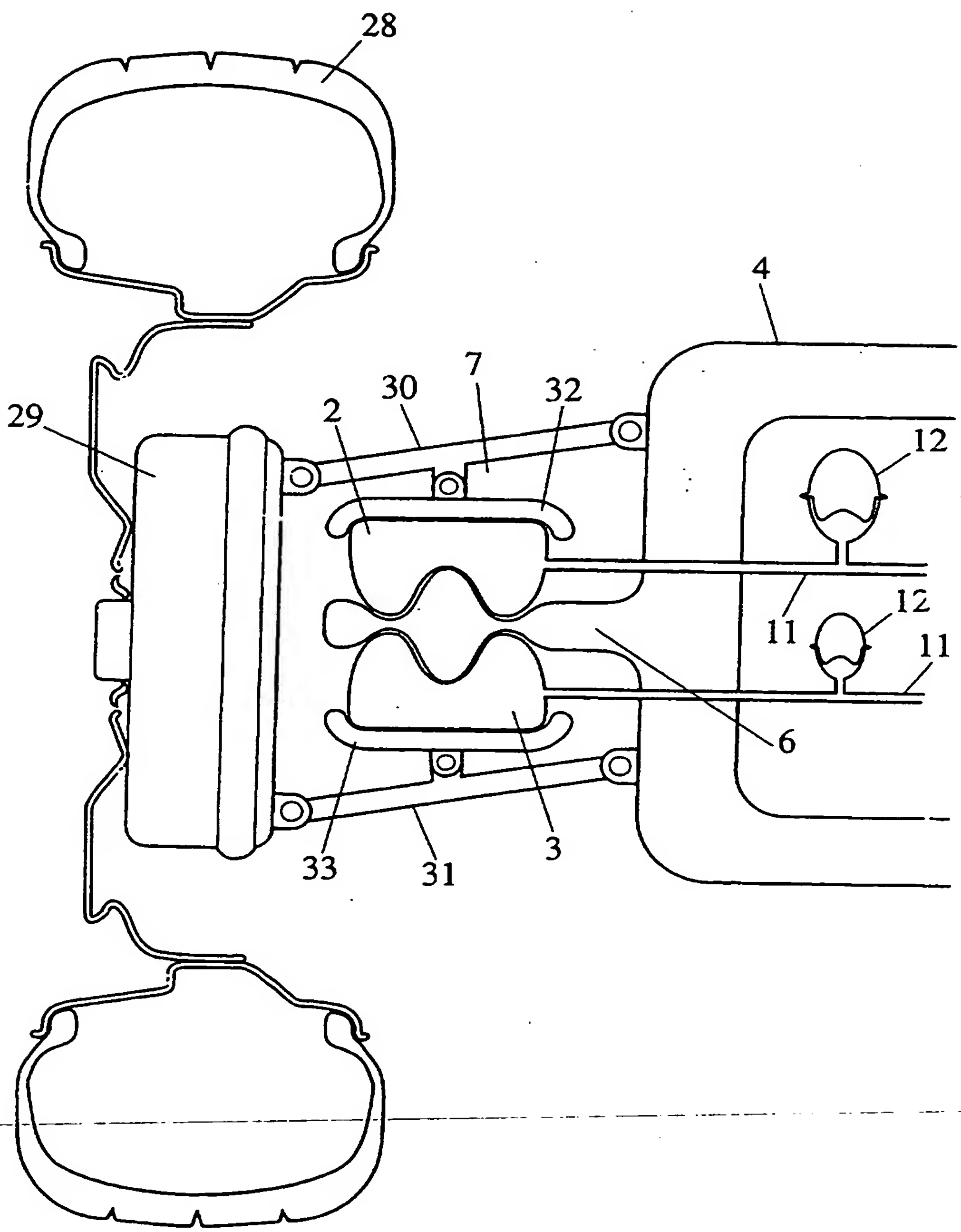


Fig 6.

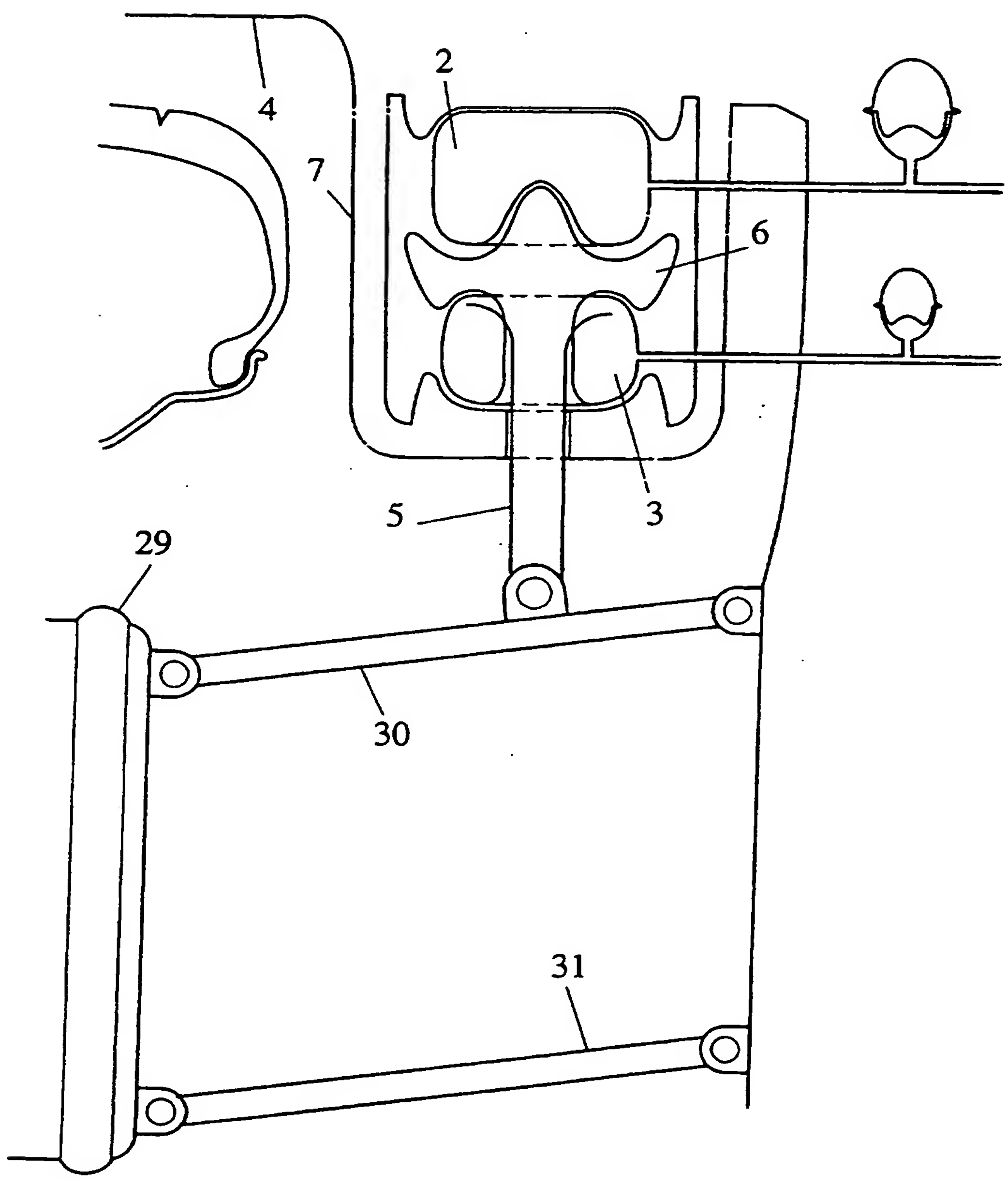


Fig 7.

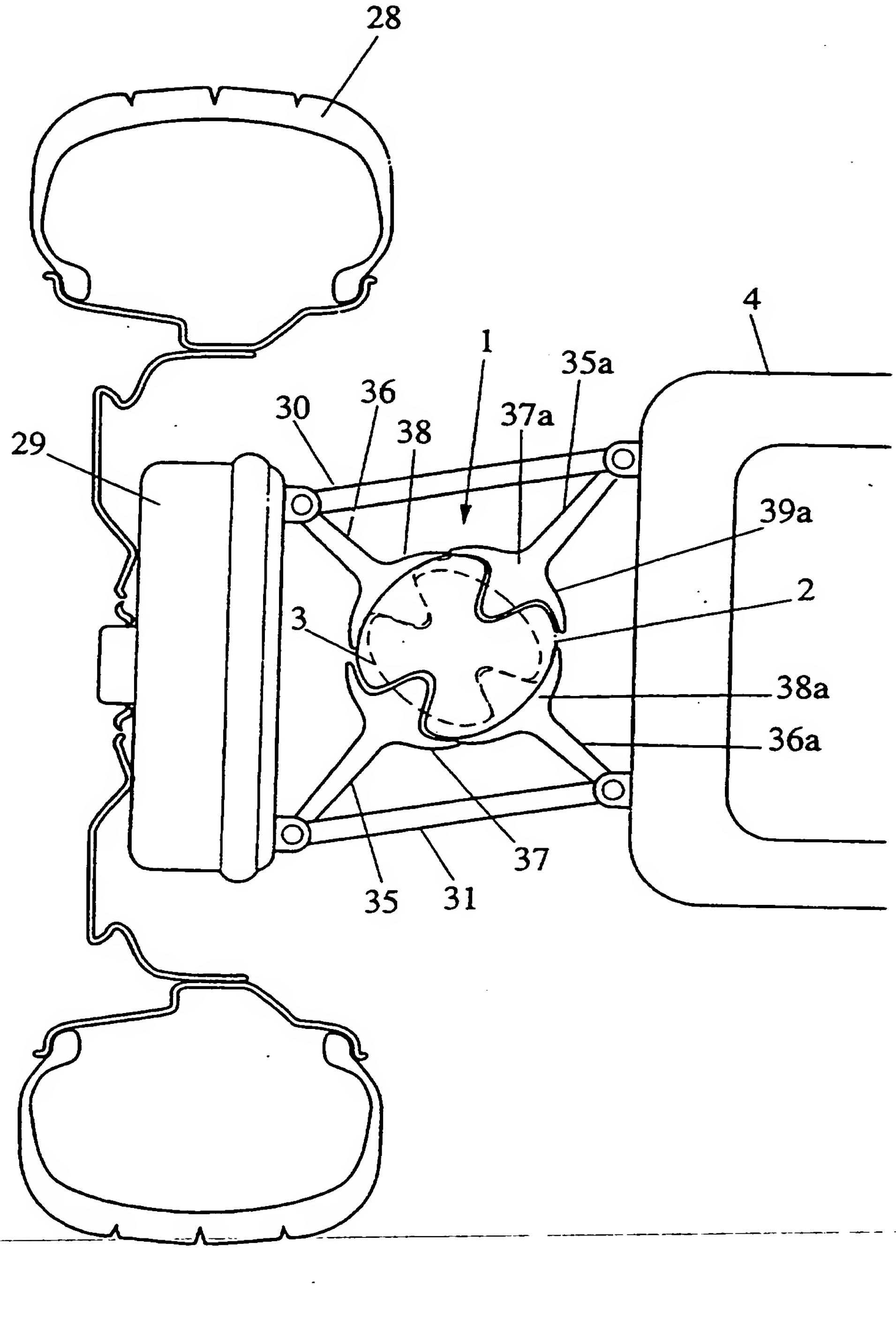


Fig 8.

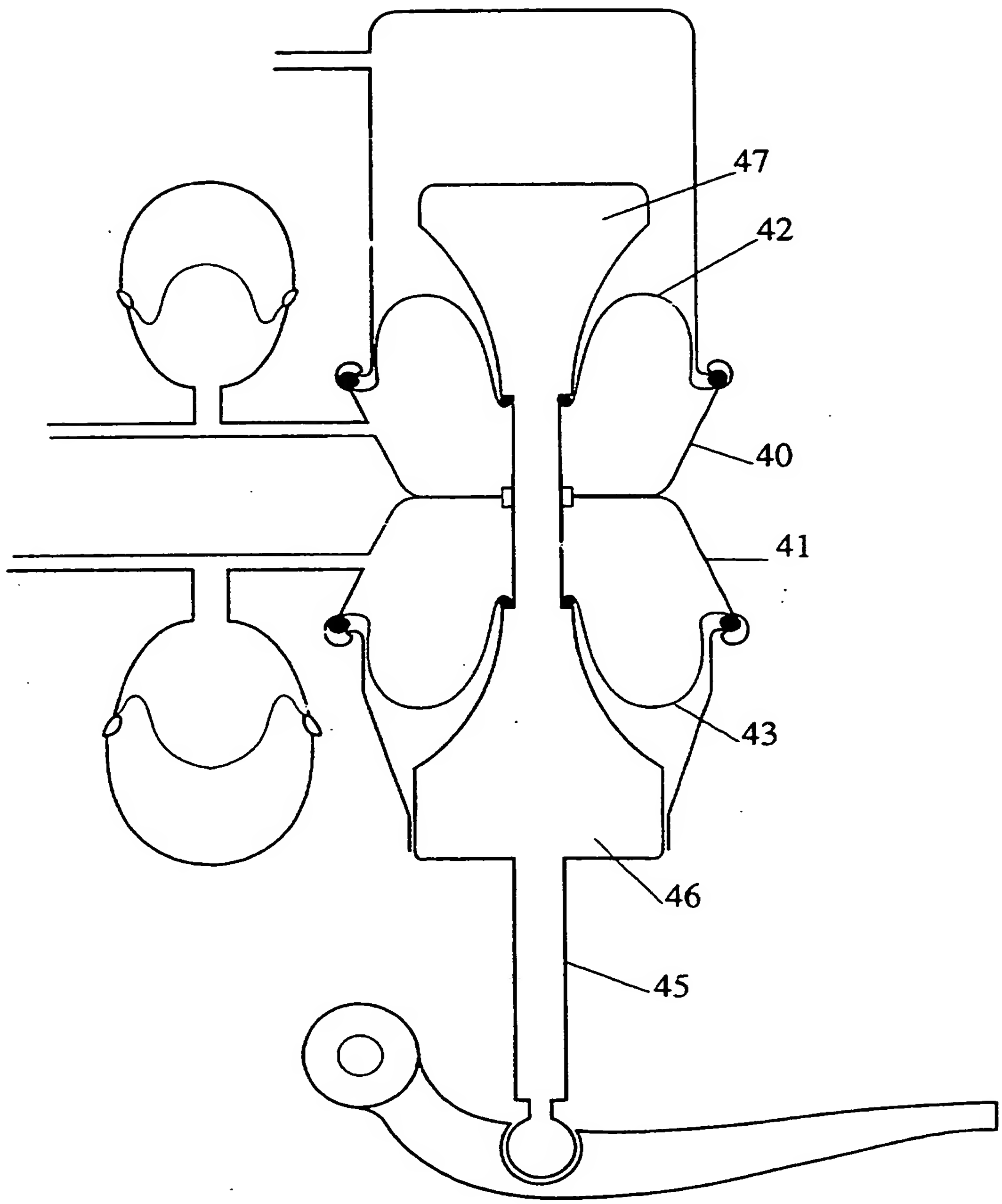
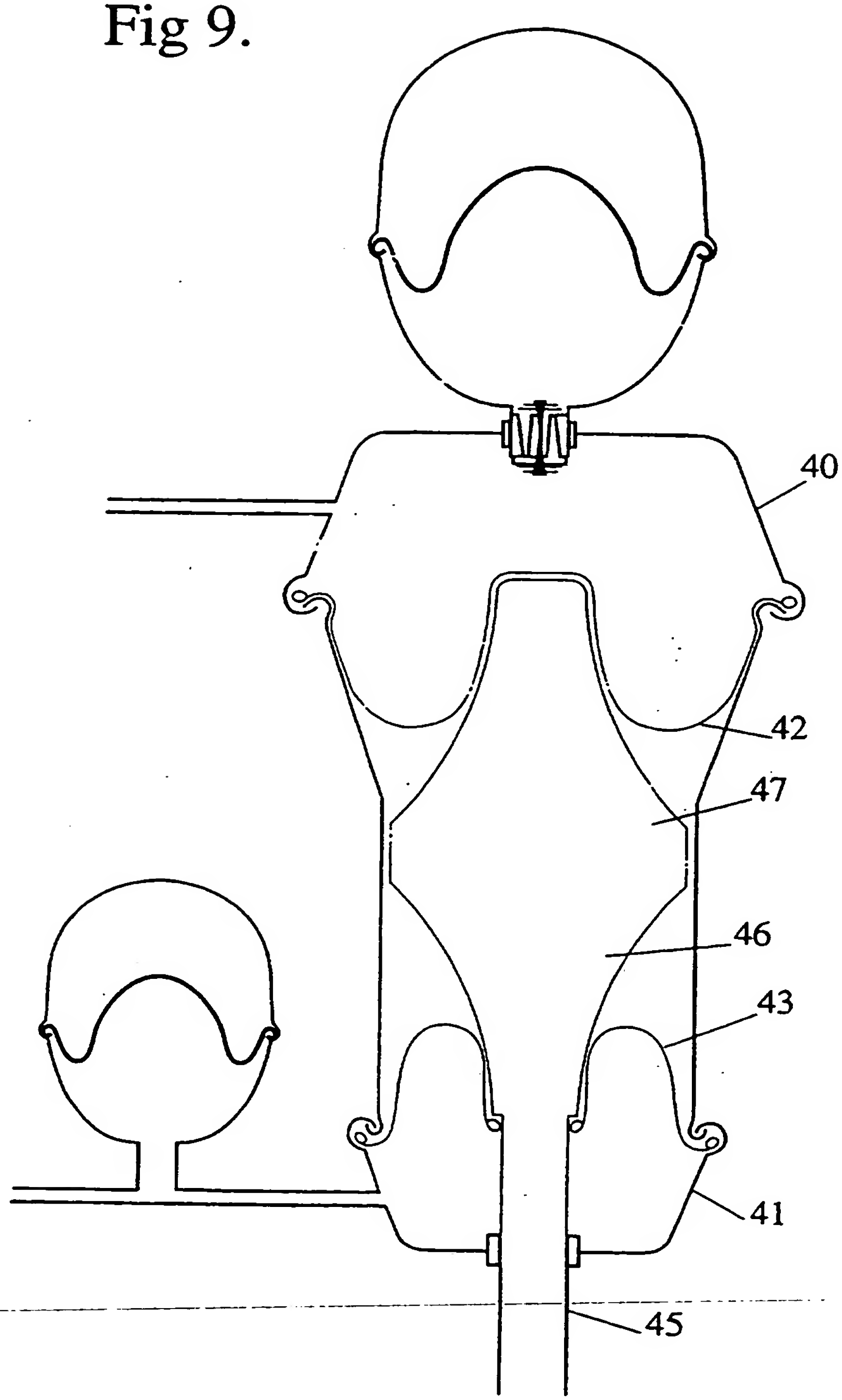


Fig 9.



FLUID ACTUATING ASSEMBLIES FOR VEHICLE SUSPENSION SYSTEM.

The present invention is directed to fluid actuating assemblies for a vehicle suspension system.

The applicant has developed various pressure vehicle suspension systems which use fluid actuators to effect the roll and articulation control and load distribution control for the vehicle. Such systems are described in US patent 5447332 and US Patent 5480188, details of which are incorporated herein by reference. In each of these abovenoted patent documents, the described suspension systems use fluid actuators in the form of double acting rams to effect the abovenoted control. Such actuators incorporate an elongate fluid chamber separated into two minor chambers by a piston. One or two double acting fluid rams interconnect the chassis of the vehicle with the support assemblies of the vehicle in each of the above described suspension systems.

Because changes in the vehicle and vehicle support assembly dynamics can be rapid and unpredictable, the vehicle suspension system needs to be able to respond rapidly to such changes. A problem associated with such piston and cylinder assemblies is that of stationary friction or "stiction" where there is an initial resistance to any movement of a stationary piston. This undesirable effect is especially prevalent in the rod seals of the double acting fluid rams where the pressure difference across the seals (from fluid pressure to atmosphere) energises the seal firmly into the sealing surface (the rod) giving high levels of friction. It is commonly found that there is only a certain reduction of the energising force possible (giving a correspondingly limited reduction in friction levels) whilst still maintaining a low fluid loss seal. This friction level causes forces input to the wheel hubs by uneven road surfaces to be transmitted to the suspension cylinder mounts on the vehicle chassis which can be detrimental to the ride comfort of the vehicle.

It is therefore an object of the present invention to overcome the abovenoted problem.

With this in mind, according to one aspect of the present invention, there is provided a fluid actuator for a suspension system of a vehicle including:

first and second fluid containers containing a fluid, at least a portion of the fluid container being defined by a flexible container wall; and

piston means engaging said fluid containers for deforming said flexible container walls.

This arrangement avoids the problem of stiction and thereby provides faster response times for the vehicle suspension system.

The piston means may include a piston assembly having a piston supported between and against the first and second fluid container, wherein the piston is moveable between the fluid containers, the fluid containers respectively applying a resultant force on the piston.

The fluid container may be in the form of a flexible bag. Alternatively, the flexible portion of the fluid container may be defined by a flexible diaphragm.

Support means may be provided for supporting the fluid containers where they are in the form of flexible bags. The bag support means may be interconnectable with the chassis of the vehicle, and the piston assembly may be interconnectable with a support assembly of the vehicle. The bag support means may be in the form of a support member extending from and supported on the chassis to locate the bags in their respective working positions. The piston assembly may therefore be connected to and moveable together with the vehicle support assembly. The piston assembly may for example be coupled to the wheel axle or wishbone connection between the wheel and the chassis, where the vehicle is supported on wheels. Alternatively, the bag support means may be interconnectable with the vehicle support assembly, and the piston assembly may be interconnectable with the vehicle chassis. In this arrangement a support member for locating the bags may be coupled with and may be moveable with the vehicle support assembly and the piston assembly may extend from and be supported by the vehicle chassis. In both arrangements, there will be relative movement between the bag support member and the piston assembly when the vehicle support assembly moves relative to the chassis.

The fluid bags may be shaped to facilitate the support of the bags by the bag support means and/or the piston. To this end, the fluid bags may for

example be substantially circular or oval in cross-section having substantially planar faces on opposing sides thereof. Alternatively the fluid bags may be toroidal in shape. Other shapes are also envisaged.

The piston may have opposing piston faces abutting the first and second bags respectively. At least one of the piston faces may include a projection which may extend from the piston face. The projection may be generally centrally located on the piston face and may for example have steeply inclined sides and be topped with a domed end portion. This profile controls the amount of fluid displaced from the bag for a given magnitude input such that the piston shape can provide a variable displacement which can be tailored to the suspension system requirements. When the piston initially moves towards the bag, only the domed end portion of the projection displaces fluid from the bag, resulting in only a small change in the force on the piston due to the bag. As the piston moves further towards the bag, a greater volume of fluid is displaced giving a larger increase in the force applied by the bag to the piston. By individually shaping the projections which contact the first and second bags, the rates at which fluid is admitted or expelled from each bag may be modified to influence the fluid flows and therefore pressures throughout the suspension system to give the required variable rate resultant force for each actuator or even make the rate more linear.

The piston means of the fluid actuator may alternatively include first and second piston assemblies cooperating with the first and second bags respectively, said piston assembly including a pair of pistons located on opposing sides of the associated bag. Each pair of pistons may be moveable towards each other to compress the associated bag. One of each said pair of pistons may be coupled to the vehicle chassis whereas the other of each said pair of pistons may be coupled to the vehicle support assembly.

Where only a portion of the fluid container is flexible, each container may include a rigid portion such as a rigid cup-shaped piece and a flexible diaphragm joined between the lip of the cup-shaped piece and the piston assembly. The diaphragm may be of a size and shape to permit relative motion between the piston and the cup to the extent of the required actuator travel. As

with the other actuator embodiments described herein, the actuator is preferably located in a position within the suspension linkage which confers a mechanical advantage or lever ratio upon the actuator. This reduces the actuator stroke required for any particular wheel or axle working range and may be desirable for any of the actuators described herein.

With the combined cup and diaphragm type actuator above, if a single double-acting actuator is formed, it is necessary in many forms to provide a running seal on the rod which can introduce the aforementioned undesirable friction characteristics. To overcome this the rod can be divided and routed around the containers. Alternatively, two opposed single-acting actuators of the combined cup and diaphragm type may be used.

In the applicant's abovenoted suspension systems, at least one of the top and bottom fluid chambers of each double acting ram are interconnected by conduits to the fluid chambers of another double acting ram and also to the chambers of a load distribution unit as for example shown in US Patent 5447332 and international application PCT/AU95/00096.

The fluid actuators according to the present invention may replace the double acting rams in the described suspension systems, with the fluid container in each fluid actuator corresponding to the fluid chambers of each double-acting ram.

Therefore, according to another aspect of the present invention, there is provided a suspension system for a vehicle having a load supporting body and at least four vehicle support assemblies connected to said body in a manner to support the body and to permit substantially vertical relative motion of the respective support assemblies relative to the body,

the fluid actuator including first and second fluid containers containing a fluid, at least a portion of the fluid container being defined by a flexible container wall; and

piston means engaging said fluid containers for deforming said flexible container walls;

said fluid actuators being functionally interconnected by interconnection means adapted to provide substantially no articulation stiffness whereby vertical

movement of two diagonally disposed support assemblies in a similar direction relative to the body induces substantially free vertical movement of two other diagonally disposed support assemblies in an opposite direction,

the interconnection means including fluid communication means to provide direct fluid communication between at least two pairs of fluid pressure means and being arranged to provide pitch stiffness in the longitudinal direction and roll stiffness in the lateral direction, and

the suspension system thereby providing substantially equal loading on each support assembly irrespective of the relative vertical positions of the support assemblies minimising roll movement in the lateral direction and providing a controlled degree of pitch movement in the longitudinal direction.

The fluid containers of each fluid actuator may be in fluid communication through conduits with the fluid containers of at least one other fluid actuator, with the connection arrangement corresponding with the applicants' above described suspension systems. The fluid contained in the fluid containers may be incompressible fluid such as hydraulic oil and accumulators may be provided along the conduits to provide a degree of resilience for the system. Alternatively, the fluid may be compressible fluid such as air and no accumulators are therefore required.

It will be convenient to further describe the invention by reference to the accompanying drawings which illustrate possible arrangements of the fluid actuator of the present invention. Other arrangements of the invention are possible and consequently the particularity of the accompanying drawings is not to be understood as superseding the generality of the preceding description of the invention.

In the drawings:

Figures 1 to 9 are respectively schematic side views of alternative fluid actuator arrangements according to the present invention.

Figures 1 to 7 are directed to fluid actuators wherein the fluid containers are in the form of flexible bags. Referring initially to Figure 1, there is shown a first arrangement of a fluid actuator 1 according to the present invention. This fluid actuator 1 includes a first bag 2, which will be referred to as the

compression bag, and a second bag 3, which will be referred to as the rebound bag. These bags are located in their working position by a bag support assembly 7 extending from and connected to the vehicle chassis 4. The bag support assembly 7 includes two side arms 8 extending from the chassis 4, only one of the side arms 8 being shown, and a bottom shoe 9 upon which the rebound bag 3 is supported. An upper shoe 10 is located on the chassis 4 to help position the compression bag 2.

The fluid actuator 1 further includes a piston assembly 5 which includes a piston 6 located between and engaging each of the bags. The piston assembly 5 is also in the form of a hoop having side arms 13 located on either side of the bag support member 8 and a bottom arm 14 coupled to a suspension load joint 17 of the wheel assembly of the vehicle (not shown). The piston 6 has opposing upper and lower piston faces 15, 15a with a projection 16 extending centrally from both piston faces 15, 15a. These projections 16, 16a may have the general shape of a cone with inclined sides and be topped with a dome portion 22, 22a.

Each of the bags are connected via conduits 11 to bags of other fluid actuators 1 of the suspension system. Accumulators 12 are optionally provided in each of the conduits 11.

The compression bag 2 has a larger area than the rebound bag 3 because both bags generally contain fluid at similar pressures, so a differential area is required to support the weight of the vehicle.

The working of this fluid actuator 1 is now described with respect to the situation when the vehicle wheel hits a bump. Following the hitting of the bump, the suspension load joint 17 moves generally upwardly with respect to the orientation of the actuator as shown in Figure 1. This results in an upward movement of the piston assembly 5 such that the piston 6 moves upwardly against the compression bag 2. The projection 16 of the piston face 15 therefore presses into the compression bag 2. Because the piston starts off in an intermediate position the projection 16 is in contact with the bag for approximately half its length, and as the initial motion takes place fluid is displaced from the bag at a relatively constant rate. As the piston continues upwards, the area of the piston increases causing a larger displacement of fluid

for a similar magnitude of piston motion. This raises the pressure in the compression bag at an increasing rate providing an increasing resultant force acting on the piston.

The increasing resultant force urges the piston 6 back in a downward direction such that the rebound piston face 15a presses against the rebound bag 3. The rebound piston face 15a similarly has a projection 16a such that the counterbalancing force applied by the rebound bag 3 progressively increases as the piston 6 moves downwardly providing a further decrease in the resultant force acting on the piston thereby reducing the rate at which the wheel rebounds as it nears the end of its travel.

The interaction of the forces applied by both the compression bag 2 and the rebound bag 3 eventually bring the piston 6 to a working position determined in part by the amount of fluid retained in each of the said bags. This is influenced by the amount of fluid delivered to or removed from each bag through the conduits 11. The position of the pistons 6 and therefore the wheel and the associated suspension load joint axle 17 relative to the vehicle chassis 4 can therefore be controlled by this fluid actuator 1.

Figure 2 shows an alternative arrangement of a fluid actuator 1 according to the present invention. Identical reference numerals are used for corresponding components for clarity purposes. This arrangement differs from the arrangement of Figure 2 in that the suspension load joint 17 is now located in an intermediate position relative to the compression bag 2 and the rebound bag 3. The piston assembly 5 is therefore pivotable about the suspension load joint 17. The bag support assembly 7 includes a single side arm 8 extending from the chassis 4 and supporting the bottom shoe 9.

In the fluid actuators of Figures 1 and 2, the bags are generally cushion shaped. In Figure 3, the rebound bag 3 is toroidal such that the piston assembly 5 includes a piston arm 20 which can be accommodated within an opening 18 provided through the toroidal rebound bag 3.

The fluid actuator arrangement shown in Figure 4 is a reverse of the arrangement of Figure 3 in that the piston assembly 5 is now supported on the vehicle chassis 4 whereas the bag support assembly 7 is now coupled to the

suspension load joint 17. The location of the fluid bags are also reversed with the compression bag 2 being located below the rebound bag 3. The piston 6 has relatively flat faces 15, 15a, and a projection 16 similar to the piston projections of the previous arrangements is provided on the bottom arm of the bag support assembly 7. This projection 16 abuts the compression bag 2 such that upward motion of the wheel and therefore the suspension load joint 17 relative to the chassis 4 presses the projection 16 into the compression bag 2. An axial bore 21 extends through the piston arm 20 to provide a passage for the conduit 11 extending from the compression bag 3. In all of the arrangements in figures 1 to 6, the conduits 11 may be run along or inside parts which are fixed to the chassis of the vehicle, then into the fluid bags. This removes the need for flexible hoses which may otherwise have to move with relative motion between the wheel assembly and the chassis.

The fluid actuator arrangement shown in Figure 5 is adapted for a wheel support assembly for a wheel 28 and incorporating upper and lower wishbones 30, 31 pivotally connecting a wheel hub 29 to the vehicle chassis 4. The bag support assembly 7 is provided by an rebound shoe 32 pivotally coupled to the upper wishbone 30 and a compression shoe 33 pivotally coupled to the lower wishbone 31. The piston 6 is fixed to the chassis 4 and located intermediate the two bags.

The fluid actuator arrangement shown in Figure 6 is identical to the arrangement shown in Figure 3 except that the piston assembly 5 is now shown pivotally coupled to the upper wishbone 30 of the wheel support assembly.

All of the above noted arrangements operate in the same general manner with a single piston 6 being located between the compression bag 2 and the rebound bag 3. Figure 7 shows an alternative arrangement of a fluid actuator 1 according to the present invention for a wheel support assembly having upper and lower wishbones 30, 31. The compression bag 2 and the rebound bag 3 are however each separately supported between a pair of piston assemblies 35, 35a, 36, 36a. Figure 7 shows the compression bag 2 in front of the rebound bag 3. Each piston assembly has a piston 37, 37a, 38, 38a with a projection as in the earlier arrangements. The adjacent pairs of piston assemblies are however

respectively pivotally coupled to diagonally disposed pivots of the wishbones 30, 31. The fluid actuator 1 is arranged such that any upward movement of the wheel 28 compresses the compression bag 2 with the rebound bag 3 providing the subsequent counterbalancing force during rebound of the fluid actuator 1.

Figures 8 and 9 are directed to fluid actuators where the fluid containers consist of a cup shaped rigid body 40, 41 and a flexible diaphragm 42,43 located over the mouth of the rigid body. A piston assembly 45 having first and second piston portions 46, 47 respectively engage the flexible diaphragm of each fluid container. These actuators operate in the same manner as the abovedescribed fluid actuators.

All of the above described fluid actuators can replace the double acting rams used in the applicant's vehicle suspension systems and in any other suspension system incorporating such rams. A comparison of the fluid actuators according to the present invention with a double acting ram shows that each fluid container corresponds to a fluid chamber of a double acting ram. Therefore, such fluid containers can similarly replace the fluid chambers provided in the load distribution units shown in the applicant's above noted patent and patent application. It should be noted that although the above descriptions detail vertically mounted actuators, the fluid actuators may be inclined or even horizontally mounted and driven by any known lever or radius arm arrangement.

CLAIMS:

1. A fluid actuator for a suspension system of a vehicle including:

first and second fluid containers containing a fluid, at least a portion of the fluid container being defined by a flexible container wall; and

piston means engaging said fluid containers for deforming said flexible container walls.

2. A fluid actuator according to claim 1 wherein the fluid container is in the form of a flexible bag.

3. A fluid actuator according to claim 2, wherein the piston means includes a piston assembly having a piston supported between and against the first and second fluid containers, the piston being moveable between the fluid containers, the fluid containers respectively applying a force on the piston.

4. A fluid actuator according to claim 3 including support means for supporting the fluid containers, wherein the support means is interconnectable with a chassis of the vehicle, and the piston assembly is interconnectable with a support assembly of the vehicle.

5. A fluid actuator according to claim 4 wherein the support means includes a support member extendible from the chassis for respectively locating the fluid containers in a working position thereof, and the piston assembly is connectable to and moveable with the wheel assembly such that there is relative movement between the support member and the piston assembly when the support assembly moves relative to the chassis.

6. A fluid actuator according to claim 3 including support means for supporting the fluid containers, wherein the support means is interconnectable with a support assembly of the vehicle, and the piston assembly is interconnectable with a chassis of the vehicle.

7. A fluid actuator according to claim 6 wherein the support means includes a support member connectable to the support assembly for respectively locating the fluid containers in a working position thereof, and the piston assembly is connectable to the chassis such that there is relative movement between the support assembly member and the piston assembly when the support assembly moves relative to the chassis.

8. A fluid actuator according to any one of claims 3 to 7 wherein the fluid containers are at least substantially circular or oval in cross-section having at least substantially planar faces on opposing sides thereof.

9. A fluid actuator according to any one of claims 3 to 7 wherein the fluid containers are at least substantially toroidal in shape.

10. A fluid actuator according to any one of claims 3 to 9 wherein the piston has opposing piston faces abutting the first and second fluid containers respectively.

11. A fluid actuator according to claim 10 wherein at least one of the piston faces includes a projection extending therefrom.

12. A fluid actuator according to claim 11 wherein the projection is at least substantially centrally located on the piston face, has relatively steeply inclined sides and is provided with a domed end portion.

13. A fluid actuator according to claim 2 wherein the piston means of the fluid actuator includes first and second piston assemblies cooperating with the first and second fluid containers respectively, said piston assembly including a pair of pistons located on opposing sides of the associated fluid container, each pair of pistons being moveable towards each other to compress the associated fluid container.

14. A fluid actuator according to claim 13 wherein one of each said pair of pistons is coupled to a chassis of the vehicle whereas the other of each said pair of pistons is coupled to a support assembly of the vehicle such that relative movement between the support assembly and the chassis of the vehicle produces a compression of one said fluid container and an expansion of the other said fluid container.

15. A fluid actuator according to claim 1, wherein the flexible portion of the fluid container is defined by a flexible diaphragm, the piston means including a piston assembly having a piston engaging the flexible respective diaphragms, each fluid container thereby applying a force on the piston.

16. A fluid actuator according to claim 15 wherein each fluid container includes a rigid cup-shaped piece, with the flexible diaphragm being joined between lips of the cup-shaped piece, the diaphragm being of a size and shape to permit relative motion between the piston means and the cup-shaped piece.

17. A fluid actuator according to claim 16 wherein the piston means includes a piston having opposing piston faces abutting the flexible diaphragm of each container.

18. A fluid actuator according to claim 17 wherein the piston is located between the flexible diaphragms and at least one of the piston faces includes a projection extending therefrom.

19. A fluid actuator according to claim 17 wherein the piston includes opposing enlargened ends, each end being respectively located within a said fluid container and abutting a said flexible diaphragm.

20. A suspension system for a vehicle including fluid actuators according to any one of the preceding claims.

21. A suspension system for a vehicle having a load supporting body and at least four vehicle support assemblies connected to said body in a manner to support the body and to permit substantially vertical relative motion of the respective support assemblies relative to the body,

the fluid actuator including first and second fluid containers containing a fluid, at least a portion of the fluid container being defined by a flexible container wall; and

piston means engaging said fluid containers for deforming said flexible container walls;

said fluid actuators being functionally interconnected by interconnection means adapted to provide substantially no articulation stiffness whereby vertical movement of two diagonally disposed support assemblies in a similar direction relative to the body induces substantially equal vertical movement of two other diagonally disposed support assemblies in an opposite direction,

the interconnection means including fluid communication means to provide direct fluid communication between at least two pairs of fluid pressure means and being arranged to provide pitch stiffness in the longitudinal direction and roll stiffness in the lateral direction, and

the suspension system thereby providing support of the vehicle body and substantially constant loading on each support assembly during cross-axle articulation motions of the support assemblies whilst simultaneously minimising roll movement in the lateral direction and providing a controlled degree of pitch movement in the longitudinal direction.

The Patent Office

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Application No: GB 9722931.4
Claims searched: 1, 21

Examiner: Howard Reeve
Date of search: 16 February 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): F2S (SBD)

Int Cl (Ed.6): B60G 11/26, 11/27, 11/30; F16F 9/02, 9/04, 9/05, 9/06, 9/08, 9/10

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2008715	(DAIMLER-BENZ), see figures 4,5	1-4, 6, 7, 9, 10, 15, 21 at least
X	US 4200270	(JOSEF MERKLE), see figures	"

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.